Chapter 2
Snow Leopard in Nepal—A Case Study

Maan B. Rokaya, Binu Timsina, and Pavel Kindlmann

Abstract The most important habitats for snow leopard in the world are in Nepal and studies on this elusive predator began there much earlier than elsewhere, but the results are scattered in the literature. The review presented in this chapter therefore aims to compile the results of the Nepalese studies, which over the last four decades consist of several published and unpublished manuscripts, and to summarize different aspects of snow leopard biology, ecology, threats and conservation with a particular emphasis on Nepal (in contrast to Chap. 1, which concentrates on global aspects). It is expected that this review will serve as a baseline for future studies and the formulation of ways of managing and conserving snow leopard in Nepal.

2.1 Introduction

There is a continuous loss of faunal diversity globally, largely due to habitat loss caused by encroachments or climate change, forest fires, landslides, developmental projects and over-exploitation of natural resources (Hoffmann et al. 2010). Of all the species, large-bodied mammals are at the greatest risk (Cardillo et al. 2005). It is estimated that about 59% of the world's biggest mammalian carnivores are listed as threatened with extinction in the International Union for the Conservation of Nature (IUCN) Red List (Ripple et al. 2016). Like many big animals (for example:

M. B. Rokaya (✉)
Institute of Botany, Czech Academy of Sciences, Zámek 1, 25243 Průhonice, Czech Republic
e-mail: rokayamaan@gmail.com

M. B. Rokaya · B. Timsina · P. Kindlmann
Department of Biodiversity Research, Global Change Research Institute, Czech Academy of Sciences, Bělidla 4a, 60300 Brno, Czech Republic
e-mail: binu.timsina@gmail.com

P. Kindlmann
e-mail: pavel.kindlmann@centrum.cz

P. Kindlmann
Faculty of Science, Institute for Environmental Sciences, Charles University, Benátská 2, 12801 Prague, Czech Republic

P. Kindlmann (ed.), *Snow Leopards in Nepal*,
https://doi.org/10.1007/978-3-031-11355-0_2

tigers, elephants, bears, musk deer, wolves, rhinoceros, spotted leopards, etc.), snow leopards are also threatened, including in the Himalayan region, where most of its important habitats occur (Chetri et al. 2017).

There are many studies on various aspects of snow leopard biology and ecology, such as taxonomy, behaviour, habitat requirements, diet, conflicts, trade, genetic diversity, seasonal movement and conservation issues (McCarthy et al. 2016). Despite an effort to bring all these studies together in a single publication (McCarthy et al. 2016), many studies are still widely scattered in various forms, such as research articles, books, reports, theses, popular articles in magazines, etc. Therefore, we attempt here to compile and summarize the results of the studies done on snow leopards in Nepal, a central Himalayan region with a rich biodiversity, in order to identify the strengths and weaknesses of these studies. It is intended that this review should serve as a baseline for future studies and for the formulation of management and conservation plans for snow leopards in Nepal (Adhikari 2004).

2.2 Data Sampling

2.2.1 Database

We reviewed scientific studies on snow leopards in Nepal published in journals, books, theses and reports. Different electronic databases were searched (ISI Web of Science, Science Direct, Scopus and Google Scholar) using specific search terms such as "Snow leopard", *Panthera uncia*", "*Uncia uncia*", "*Felis uncia*", "*Panthera uncia uncioides*", "Nepal", "Himalaya" "Himalayas" and "Himalayan region". We also carried out a library search for hard copies.

2.2.2 Literature

We consulted 93 documents related to snow leopard in Nepal. They consisted of 49 journal articles, 20 reports, 6 books, 3 book chapters, 2 conference papers, 2 magazine articles and 1 conference proceeding. Snow leopard is the topic of research for 5 master degrees (Oli 1991; Adhikari 2004; Conradi 2006; Upadhyay 2010; Bhattarai 2015) and 5 Ph.D. degrees (Jackson 1996; Ale 2007; Aryal 2013; Hanson 2017; Chetri 2018) and also the topic of books based on expeditions (Matthiessen 1978; Hillard 1990). There was a significant increase ($p = 0.0003$, $R^2 = 0.3598$) in the number of documents on snow leopards published per year from the 1970s up to September 2020 (Fig. 2.1). Similar trends are also recorded for various fields of study worldwide (Laakso et al. 2011).

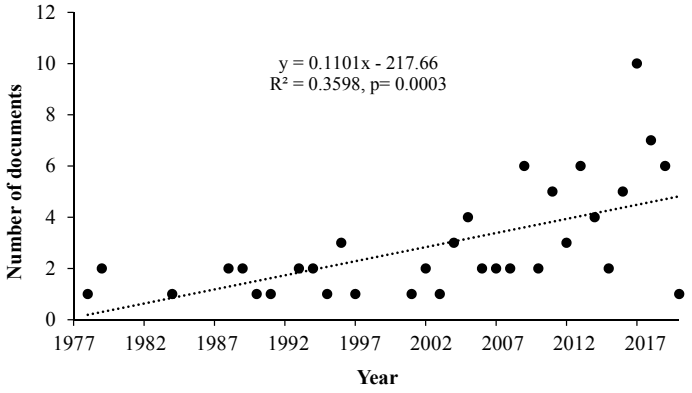

Fig. 2.1 The number of documents on snow leopards in Nepal published each year from 1978 to September 2020

Different methods are used to study snow leopards. The majority involves field surveys of their status, distribution, diet composition etc., and depends on the markings on snow leopards (e.g. Ahlborn and Jackson 1988; Wolf and Ale 2009; Shrestha et al. 2018) or the use of radio-collars to monitor them over long periods of time (Jackson and Ahlborn 1988; Oli 1994) or camera traps for relatively short periods of time (Ale et al. 2014; Lama et al. 2018). Some of the studies are also based on the literature and review different aspects, such as prey diversity (Lovari et al. 2013a; Lyngdoh et al. 2014; Valentová 2017), threats (Valentová 2017) or current knowledge and status of snow leopards in various parts of the world (McCarthy and Chapron 2003), or people's attitude towards snow leopard or the conservation of snow leopard (Khanal et al. 2018; Schutgens et al. 2018; Hanson et al. 2019a, b; Kusi et al. 2019).

Substantial numbers of studies are also based on questionnaires, informal discussions, focus group discussions, and key informant interviews on human-snow leopard conflict and attitudes of locals towards snow leopards. Genetic analyses are also used to identify density/population, gender, and the relationship between a population and other populations of snow leopards (Conradi 2006; Aryal et al. 2014a; Karmacharya et al. 2016; Chetri et al. 2017; Janecka et al. 2017).

There is even a discussion of the methods to be used for storing scats for genetic studies (Conradi 2006). A study of samples (48 sun-dried scats and 19 stored in ethanol) revealed that extraction and genotyping quality was much higher for ethanol than for the air-dried samples. Of the dry samples 25% were of sufficient quality to be genotyped, whereas it was 50% for the ethanol-preserved samples. In recent years, cameras have been used to record their status (Ale et al. 2014; Shrestha 2016; Shrestha et al. 2018), in particular, their presence and movements in a region were monitored this way.

2.2.3 Studies: Then and Now

Snow leopard first came to prominence after the publication of "The snow leopard" by Matthiessen (1978). This book was an outcome of a journey by Matthiessen and his fellow naturalist George Schaller through the Dolpo region in Nepal in 1973. Schaller's aim was to study wild blue mountain sheep and compare them with common sheep in the USA, while for Matthiessen the trip was more of a spiritual exploration. His next aim was to observe snow leopard, a predator of *bharal*, which had only been seen twice by westerners in the previous twenty-five years, and then to visit the Crystal Monastery in Tibet and the Buddhist lama there. Though they did not see any snow leopards during their journey, Matthiessen wrote "…. *it has pale frosty eyes and a coat of pale misty grey, with black rosettes that are clouded by the depth of the rich fur* …" and also "… *snow leopard is the most mysterious of the great cats; of its social system, there is nothing known. Almost always it is seen alone; it may meet over a kill, as tigers do, or it may be unsociable and solitary, like the true leopard.*" The publication of "The snow leopard" not only received a National book award in 1979, but also helped in the establishment of the Shey Phoksundo National Park that partly helped to preserve the native habitat of the snow leopard. Thus, in Nepal snow leopards were of great interest to many academicians and biologists much earlier than elsewhere in the world (Ale and Karky 2002). Following the publication of Matthiessen's book, the first scientific pioneering work was carried out by R. Jackson in the Dolphu region, in western Nepal. After Jackson, there has been a huge increase in research related to snow leopard and many publications have been emerging day by day (Chetri 2018; Schutgens et al. 2018; Shrestha et al. 2018).

2.3 Distribution of Snow Leopard in Nepal

Snow leopards occur in the northern part of Nepal. They occur in eight mountainous areas in Nepal that are protected: the Annapurna Conservation Area, Shey Phuksundo National Park, Kanchenjunga Conservation Area, Manaslu Conservation Area, Makalu Barun National Park, Dhorpatan Hunting Reserve, Sagarmatha (Everest) National Park and Langtang National Park. Snow leopards also occur in Humla, Jumla, Mugu and Shankhuwasawa regions (Jackson 1996; Lama et al. 2018). Snow leopards that were previously thought to have disappeared from the Everest region were observed there again in 2004 (Shrestha 2004, 2006; Ale and Boesi 2005). Their presence was confirmed by scats and pugmarks observed near Phortse, Namche and Ngozumpa glacier. They even suggest that there should be snow leopard in the area, as there are prey animals there, such as tahr and musk deer. Still a large part of northern Nepal is yet to be explored in detail.

2.3.1 Estimating Snow Leopard Abundance

Snow leopards leave different kinds of marks (scrapes, spray, scat, pugmarks, hair, kills) in their territories. The marks are usually surveyed using transects, as described by 'The Snow Leopard Information Management System', known as SLIMS (Jackson and Hunter 1996) or by the incidental method (Ale et al. 2014). See Chap. 3 for details of the types of marks and methods of estimating abundance. Here, we concentrate on the specific conditions in Nepal: when and how snow leopard abundance is to be estimated.

The most suitable time for seeing marks left by snow leopards or snow leopards themselves is from June to September in the Langtang National Park (Adhikari 2004). However, in western Nepal, marks are recorded more frequently during January–March (Jackson and Ahlborn 1988). The marks are found on a wide range of substrates, vegetation, upright boulders, at the base of rocky outcrops and cliffs, on the top of promontories and knolls, in the open, at the base of pine trees, near the edges of riverine terraces/bluffs, on cliff ledges exposed on the crests of ridges, and even in landslides or on river gravel and sandbars (Ahlborn and Jackson 1988). The abundance of marks varies from place to place. Scrapes are the most common type of mark and are often repeated (Schaller 1977; Ahlborn and Jackson 1988). Scat is also important, as it is quite frequently deposited (Ale et al. 2014; Devkota et al. 2017; Chetri 2018; Table 2.1). Although marks eventually disappear, spray marks are sometimes still detectable after more than 60 days and can be 80–100 cm above the ground (Ahlborn and Jackson 1988; Fox 1989).

The distances surveyed varied from 4.023 to 139.3 km. Sometimes there are seasonal differences in the marks left by snow leopards. In the Sagarmatha (Everest) National Park more scats (66) were recorded in autumn than in summer (40) (Lovari et al. 2009). In Mustang, more marks were recorded in spring (112) than in autumn (66) and summer (41). There were more marks recorded in upper Mustang at high altitudes (121) than in lower Mustang at low altitudes (98) (Ale et al. 2014). The occurrence of the different marks also depends on population size, age/sex ratio and also on the type of habitat (Ahlborn and Jackson 1988).

2.3.2 Population Status

In 1972 Schaller estimated that there were three individuals near Lepche in the Bhote Koshi valley in east Nepal (Schaller 1973). Schaller, after surveying about 500 km^2 in 1973 at Shey gompa and Phoksundo lake in Dolpa, estimated that there were at least six snow leopards in this area, especially during winter months when they roam around searching for food (Schaller 1977). The first in-depth study was carried out in the Langu valley in western Nepal, where radiometry results were compared with the abundance of signs of their presence (Jackson 1979a; Jackson and Ahlborn 1988).

Table 2.1 Abundance of signs of snow leopard presence in different parts of Nepal

Place	Area surveyed using transects (km)/area	Total number of signs	Most frequent sign	Number of signs per km	Individual sign density (sign/km)	References
Langu valley, western Nepal	4.908	–	Scrapes	–	Single sign every 204 ± 71 m	Jackson and Ahlborn (1988)
Chhekampar VDC, Gorkha, central Nepal	8.12	29 (faeces 14, scrapes 8, pugmark 7)	Scrapes	3.57	0.99	Devkota et al. (2017)
Langtang region, central Nepal	–	90	–	2.4–11.75 at 4000–4810 m a.s.l. (7.74 signs) and at 3700–4000 m a.s.l. (6.21 signs)	2–9.14	Adhikari (2004)
Kanchenjunga conservation area, eastern Nepal	18.01	200	Scrapes	–	–	Khatiwada and Chalise (2006)
Everest region	13.9 km (2004), 5 km (2005)	193 signs and 252 incidental signs	Scrapes	4.5	3.2	Ale (2005, 2007)
Shey Phoksundo National Park, western Nepal	4.475	46 (25 scats, 10 scrapes, 10 pugmarks and 1 kill)	Scats	10.28	5.59	Poudel et al. (2008)

(continued)

Table 2.1 (continued)

Place	Area surveyed using transects (km)/area	Total number of signs	Most frequent sign	Number of signs per km	Individual sign density (sign/km)	References
Humla region, western Nepal	6.76	45 signs (32 scrapes, 11 faeces, 1 urine mark and 1 pugmark)	Scrapes	5.49–7.36	3.92–5.23 scrapes	Khatiwada and Ghimirey (2009)
Sagarmatha (Everest) National Park, eastern Nepal	–	223: scrape (131), followed by faeces (55), pugmark (23) and rubbing sites and also scent spray (7 each)	–	–	–	Wolf and Ale (2009)
Rolwaling	4.023	29 (9 scrapes, 13 scats, 2 pugmarks, 5 tufts of hairs)	Scrapes	3.2	2.2	Ale (2010)
Upper Mustang, central Nepal	18.47	204 (49 pugmarks, 93 scrapes, 49 faeces, 10 urine spray, 1 rock scent, 1 hair sample and 1 kill)	Scrapes	10.8	6.8	Upadhyay (2010)
Upper Mustang, central Nepal	49.6	292	Scrapes	5.89	2.63	Aryal (2011)
Mustang, central Nepal	19.4	296: faeces (70), pugmark (31), scrapes (188), spray (6), hair (1)	Scrapes	5.8	2.8	Ale et al. (2014)

(continued)

Table 2.1 (continued)

Place	Area surveyed using transects (km)/area	Total number of signs	Most frequent sign	Number of signs per km	Individual sign density (sign/km)	References
Upper Mustang, central Nepal	59.9	283	Scrapes	4.72	2.85	Aryal et al. (2014a)
Annapurna Conservation Area (ACA) and the Manaslu Conservation Area (MCA)	–	573	–	–	–	Chetri et al. (2019b)
Sagarmatha National Park and the Annapurna Conservation Area (Lower Mustang and Upper Manang)	139.3	268	–	–	–	Shrestha et al. (2018)

Dash (–) Data not available

In 1979, it was estimated that there were about 150–300 snow leopards in Nepal (Jackson 1979a) and the most recent estimate (WWF 2009) is that there are around 300–400.

The estimated density is 5–10 individuals/100 km^2 in western Nepal (Jackson and Ahlborn 1988), 4.8–6.7/100 km^2 in Manang (Oli 1994), 1–3 individuals/100 km^2 in the Everest region (Ale 2005, 2007), 9 of which were resident (it is likely that five of them constituted a family group with a resident male and female and three cubs, with the rest most likely roaming animals attracted to the valley during the mating season) in the Phu valley. A subsequent estimate for Manang is 10.4 individuals/100 km^2) (Conradi 2006). Similarly, there were 7 individuals/100 km^2 in the Everest region (Lovari et al. 2009), 5–6 individuals/100 km^2 in the northern part of Langtang National Park (Chalise 2011), 9 individuals/100 km^2 in the Shey Phoksundo National Park (Karmacharya et al. 2011), 10–12 individuals/100 km^2 in the Langu valley, 4.8–6.7 individuals/100 km^2 in Manang (Thapa 2011), 6 (four females and two males) in an area of about 125 km^2 in Phu valley (Wegge et al. 2012), at least 3 adults at Mustang (Ale et al. 2014), 5 individuals (3 males and 2 females) in an area of 264.7 km^2 with a population density of 1.9 individuals/100 km^2 in upper Mustang (Aryal et al. 2014a), 5 individuals in 2007 (10.9/100 km^2) and two in 2010 (4.3/100 km^2) in Sagarmatha (Everest) NP (Ferretti et al. 2014), 6 in lower Mustang in 2014 and 8 in upper Manang in 2016, based on records of camera traps (Shrestha 2016), and 34 individuals of which 20 were males and 14 were females in the Annapurna Conservation Area (ACA) and the Manaslu Conservation Area (MCA) (Chetri et al. 2019b). Likewise, the density in western Nepal was estimated to be 3.2 individuals/100 km^2, in Rolwaling 1.5 individuals/100 km^2, in Sagarmatha NP 1.8 individuals/100 km^2 and in Kanchenjunga 2.6 individuals/100 km^2 (WWF 2009). These figures show that the population status is not uniform throughout the country, it is changing with time and more studies are needed.

2.3.3 Habitat Ecology and Home Range

Snow leopards were generally found in the areas with low rainfall at between 3000 and 5000 m and sometimes recorded even up to 5600 or 6000 m in Nepal (Jackson and Ahlborn 1984; Jackson 1996; Upadhyay 2010; Aryal et al. 2014a). The widest altitudinal range was recorded in upper Mustang and that between 2900 and 6000 m (Aryal 2011). Most snow leopards occur at altitudinal ranges of between 4000 and 4500 m and rarely at lower altitudes (Aryal et al. 2014a).

In Nepal, snow leopards normally occupy rugged mountainous terrain (Jackson and Ahlborn 1988). Such terrain is characterized by rocky outcrops, ridges, cliffs, gorges, stream beds of gravel and sandbars, vegetation dominated by grasses and sedges, shrubs or trees, broken or very broken ruggedness, rolling and flat ruggedness, with grassland, shrub land and both grass and shrub land, mixed and barren habitats without any vegetation or less grazed areas, forest borders or open shrub land/alpine meadows, and sometimes cultivated fields and areas subject to landslides (Figs. 2.2,

Fig. 2.2 Snow leopard habitat in high mountains in Mustang district, Nepal. *Photo by* M. Rokaya

2.3 and 2.4) (Jackson and Ahlborn 1988; Adhikari 2004; Lovari et al. 2013a; Aryal et al. 2014a; Upadhaya 2017). However, snow leopards avoid agricultural areas, glaciers and human settlements, and instead use barren land and grassland in Mustang (Aryal et al. 2014a). Of all the different types of habitats, ridgelines, narrow valleys, trails and cliff-edges are most frequently used by snow leopards for moving about their home range (Jackson and Hunter 1996). Snow leopards are active during the night, bedding in different places each day unless searching for prey (Jackson and Ahlborn 1989; Jackson 1996).

Total range of snow leopards is about 30,000 km^2 in Nepal (Fox 1989) and the estimated potential range is 27,432 km^2, of which 26.7% is in protected areas (PA). However, snow leopards depend on an abundance of food, enough cover for shelter, availability of escape routes, enough food for reproduction and absence of hunting.

There are concerns that the current increase in temperature will result in a reduction in the area of suitable habitat. Habitat modelling of snow leopard in six countries (Bhutan, China, India, Myanmar, Pakistan and Nepal) indicate that about 30% of snow leopard habitat in the Himalayan region may be lost due to an upward shift in the tree line and consequent shrinking of the alpine zone, mostly along the southern edge of its range and in river valleys.

However, a considerable part of the snow leopard habitat and corridors are likely to be resilient to climate change, and it is these that should be protected (Forrest et al. 2012). Similarly, Aryal et al. (2016) predict the effect of climate change on the distribution of snow leopards in the Himalayas using previously and recently collected data on their distribution. This study indicates that 11.6% (17,190 km^2) of

Fig. 2.3 Snow leopard habitat in high mountains in Yak kharka in Manang, Nepal. *Photo by* M. Rokaya

Fig. 2.4 Snow leopard habitat in high mountains in Thorang La in Manang, Nepal. *Photo by* M. Rokaya

this area is currently suitable for snow leopards and will be reduced by 14.57% due to climate change by 2030 and by 21.5% by 2050. They suggest that conservation should concentrate on establishing new protected areas high up in the mountains in order to mitigate the possible effect of climate change (Aryal et al. 2016).

The home range of snow leopards in the Langu valley, western Nepal, varies from 12 to 39 km^2. The patterns of movement of males and females are different, with males moving an average distance of 1.16 km/day and females 0.64 km. Both take a zig-zag route, when moving in their home ranges (Jackson and Ahlborn 1988). The movement slightly differs when recorded using radio-collars and following their movement for 18 months. The daily movement distance of males (n = 3) is 1.3 km and 1.0 km of females (n = 2) (Jackson and Ahlborn 1989). Similarly, based on the movement of 3 radio-collared snow leopards (1 male and 2 females) at Manang, winter home ranges vary between 19.9 and 22.3 km^2, and home ranges overlap extensively within and between both sexes. The core habitat area is around 8.1 km^2 (Oli 1997). In upper Mustang, however, snow leopards patrol an area of 264.7 km^2 and females tend to roam more (59.3 km^2) than males (52.9 km^2) (Aryal et al. 2014a).

2.4 Diet of Snow Leopard in Nepal

Bharal/nayur (*Pseudois nayaur*), also called the blue sheep, is the most preferred prey in the Langu valley (Jackson and Ahlborn 1988), Mustang (Aryal 2011; Aryal et al. 2014a; Shrestha et al. 2018), Manang (Oli et al. 1993; Wegge et al. 2012; Shrestha et al. 2018), the Shey Phoksundo National Park (Devkota et al. 2013) and west Nepal (Shrestha et al. 2019). Himalayan tahr (*Hemitragus jemlahicus*) and musk deer (*Moschus chrysogaster*) are preferred prey animals in the Everest (Ale 2005; Lovari et al. 2009; Shrestha et al. 2018) and Langtang regions (Chalise 2011). However, small animals like pika (*Ochotona roylei*) are also reported as the most preferred prey in the Dhorpatan Hunting Reserve (Aryal 2009) and west Nepal (Shrestha et al. 2019). Different studies report a wide range of different species of prey (wild animals, domestic animals, birds and unidentified prey) in Nepal. There are also reports of vegetation or grass in scats (Table 2.2). The species of prey in the scats are identified by direct observation, questionnaires, interviews and analysing scats both microscopically (Oli et al. 1993; Shrestha et al. 2018) and genetically (Karmacharya et al. 2016; Chetri et al. 2017; Shrestha et al. 2018).

There is seasonal variation in the types of prey. In the Sagarmatha (Everest) National Park, Himalayan tahr is the main prey in summer (48%) and less so (37%) in autumn (Lovari et al. 2009). Wild ungulates are the most frequent prey in the cold season (78%) and less so in the warm season (33%) in the Manaslu Conservation Area. In contrast, small mammals/birds are more frequently caught in summer (74%) than in winter (22%) (Chetri et al. 2017). Likewise, in the Sagarmatha National Park (SNP), the most frequent species of prey is Himalayan tahr in both winter and summer, followed by cow and musk deer in winter, and cow and yak in summer; weasel sp. and dog are also consistently recorded in both seasons and some small prey occur

Table 2.2 List of the animals, birds, plants and unidentified items recorded in snow leopard diet

Wild	Common names	Regions and references
Alectoris chukar	Chukor Patridge	Upper Langtang National Park (Chalise 2011), Shey Phoksundo National Park (Devkota et al. 2013)
Cervus sp.	Deer	Nepal (Lovari et al. 2013a)
Equus kiang	Wild ass/Kiang	Upper Mustang (Aryal 2011), Manang and Mustang (Aryal et al. 2014a), Manaslu Conservation Area, Gorkha (Chetri et al. 2017)
Hemitragus jemlahicus	Himalayan tahr	Everest region (Ale 2005), Dhorpatan Hunting Reserve (Aryal 2009), Everest region (Shrestha 2008), Everest region (Lovari et al. 2013a), Upper Langtang National Park (Chalise 2011), Nepal (Lyngdoh et al. 2014), Manaslu Conservation Area, Gorkha (Chetri et al. 2017), Chhekampar VDC, Gorkha, Manaslu Conservation Area (Devkota et al. 2017), Lower Mustang, Upper Manang and Sagarmatha National Park (Shrestha et al. 2018)
Lepus oiostolus	Himalayan woolly hare	Manang and Mustang (Aryal et al. 2014a), Chhekampar VDC, Gorkha, Manaslu conservation area (Devkota et al. 2017), Manaslu, Gorkha (Chetri et al. 2017), Shey Phoksundo National Park (Devkota et al. 2013), Lower Mustang, Upper Manang and Sagarmatha National Park (Shrestha et al. 2018)
Lepus sp.	Hare	Everest region (Shrestha 2008), Nepal (Lovari et al. 2013a), west Nepal (Shrestha et al. 2019)
Marmot sp.	Marmot	Manang, central Nepal (Oli et al. 1993), upper Mustang (Aryal 2011), Nepal (Lovari et al. 2013a)
Marmota himalayana	Himalayan marmot	Samagaun, Manaslu Conservation Area (Bhattarai 2015), Manaslu Conservation Area, Gorkha (Chetri et al. 2017), Chhekampar VDC, Gorkha, Manaslu Conservation Area (Devkota et al. 2017), Shey Phoksundo National Park (Devkota et al. 2013)

(continued)

Table 2.2 (continued)

Wild	Common names	Regions and references
Martes foina	Marten	Manang and Mustang (Aryal et al. 2014a)
Moschus chrysogaster	Himalayan musk deer	Dhorpatan Hunting Reserve (Aryal 2009), Upper Langtang National Park (Chalise 2011), Everest region (Shrestha 2008; Lovari et al. 2009, 2013b), Chhekampar VDC, Gorkha, Manaslu Conservation Area (Devkota et al. 2017), Lower Mustang, Upper Manang and Sagarmatha National Park (Shrestha et al. 2018)
Moschus sp.	Musk deer	Manang and Mustang (Aryal et al. 2014a), Nepal (Lovari et al. 2013a)
Musela nivalis	Weasel	Manang and Mustang (Aryal et al. 2014a)
Myodes sp.	Voles	Everest region (Lovari et al. 2009), Phu valley, Manang (Wegge et al. 2012), Lower Mustang, Upper Manang and Sagarmatha National Park (Shrestha et al. 2018)
Nemorhaedus goral	Goral	Dhorpatan Hunting Reserve (Aryal 2009)
Ochotona roylei	Pika/Royle's pika	Dhorpatan Hunting Reserve (Aryal 2009), Everest region (Shrestha 2008), Upper Mustang (Aryal 2011), Shey Phoksundo National Park (Devkota et al. 2013), Manang and Mustang (Aryal et al. 2014a), Manaslu Conservation Area, Gorkha (Chetri et al. 2017), Chhekampar VDC, Gorkha, Manaslu Conservation Area (Devkota et al. 2017), west Nepal (Shrestha et al. 2019)
Ochotona sp.	Pika	Langu valley, west Nepal (Jackson and Ahlborn 1988), upper Langtang National Park (Chalise 2011), Phu valley, Manang (Wegge et al. 2012), Lower Mustang, Upper Manang and Sagarmatha National Park (Shrestha et al. 2018)
Ovis ammon hogs	Tibetan argali	Manang and Mustang (Aryal et al. 2014a), Manaslu Conservation Area, Gorkha (Chetri et al. 2017)

(continued)

Table 2.2 (continued)

Wild	Common names	Regions and references
Procapra picticaudata	Tibetan gazelle/Goa/Tibetan antelope	Upper Mustang (Aryal 2011), Manaslu Conservation Area, Gorkha (Chetri et al. 2017)
Pseudois nayaur	Bharal/Blue sheep	Dolphu region, Mugu (Poudel et al. 2008), Manang, central Nepal (Oli 1993), Dhorpatan Hunting Reserve (Aryal 2009), Upper Mustang (Aryal 2011), Phu valley, Manang (Wegge et al. 2012), Nepal (Lovari et al. 2013a), Mustang (Ale et al. 2014), Mustang (Aryal et al. 2014b), Manang and Mustang (Aryal et al. 2014a), Everest region (Ferretti et al. 2014), Nepal (Lyngdoh et al. 2014), Samagaun, Manaslu Conservation Area (Bhattarai 2015), Manaslu Conservation Area, Gorkha (Chetri et al. 2017), Chhekampar VDC, Gorkha, Manaslu Conservation Area (Devkota et al. 2017), Lower Mustang, Upper Manang and Sagarmatha National Park (Shrestha et al. 2018)
Rattus sp.	House rat	Everest region (Shrestha 2008)
Soriculus sp.	Shrew	Everest region (Shrestha 2008)
Sus scrofa	Wild boar	Dhorpatan Hunting Reserve (Aryal 2009)
Vulpes sp.	Fox	Upper Mustang (Aryal 2011), Nepal (Lovari et al. 2013a)
Vulpes vulpes	Red fox	Everest region (Shrestha 2008), Manang and Mustang (Aryal et al. 2014a), Samagaun, Manaslu Conservation Area (Bhattarai 2015)
Soriculus nigrescens	Himalayan Shrew	Chhekampar VDC, Gorkha, Manaslu Conservation Area (Devkota et al. 2017)
-	Rat spp.	Lower Mustang, Upper Manang and Sagarmatha National Park (Shrestha et al. 2018)
-	Mustelids	Lower Mustang, Upper Manang and Sagarmatha National Park (Shrestha et al. 2018)
Unidentified wild	Small mammals	Nepal (Lovari et al. 2013a)

(continued)

Table 2.2 (continued)

Wild	Common names	Regions and references
	Small rodents	Langu valley, west Nepal (Jackson and Ahlborn 1988)
	Unidentified rodents	Manaslu Conservation Area, Gorkha (Chetri et al. 2017)

Domestic	Common names	Regions and references
Bos grunnens	Yak	Manang, central Nepal (Oli 1993), Everest region (Shrestha 2008; Lovari et al. 2013b), Upper Mustang (Aryal 2011), Phu valley, Manang (Wegge et al. 2012), Manang and Mustang (Aryal et al. 2014a), Samagaun, Manaslu Conservation Area (Bhattarai 2015), Manaslu Conservation Area, Gorkha (Chetri et al. 2017), Nepal (Lovari et al. 2013a), Lower Mustang, Upper Manang and Sagarmatha National Park (Shrestha et al. 2018), west Nepal (Shrestha et al. 2019)
Bos sp.	Cow	Everest region (Shrestha 2008), Lower Mustang, Upper Manang and Sagarmatha National Park (Shrestha et al. 2018), west Nepal (Shrestha et al. 2019)
Bos sp.	Yak	Everest region (Lovari et al. 2009)
Bos sp.	Bovine	Manang and Mustang (Aryal et al. 2014a)
Cannis familiaris	Dog	Everest region (Shrestha 2008), Everest region (Lovari et al. 2013b), Nepal (Lovari et al. 2013a), Lower Mustang, Upper Manang and Sagarmatha National Park (Shrestha et al. 2018)
Capra sp.	Goat	Dhorpatan hunting reserve (Aryal 2009), Everest region (Shrestha 2008), Upper Mustang (Aryal 2011), Phu valley, Manang (Wegge et al. 2012), Nepal (Lovari et al. 2013a), Manang and Mustang (Aryal et al. 2014a), Nepal (Lyngdoh et al. 2014), Samagaun, Manaslu Conservation Area (Bhattarai 2015), Manaslu Conservation Area, Gorkha (Chetri et al. 2017), Lower Mustang, Upper Manang and Sagarmatha National Park (Shrestha et al. 2018), west Nepal (Shrestha et al. 2019)
Equus asinus	Donkey	Nepal (Lovari et al. 2013a)
Equus caballus	Horse	Dhorpatan Hunting Reserve (Aryal 2009), Everest region (Shrestha 2008), Upper Mustang (Aryal 2011), Phu valley, Manang (Wegge et al. 2012), Nepal (Lovari et al. 2013a), Manang and Mustang (Aryal et al. 2014a), Manaslu Conservation Area, Gorkha (Chetri et al. 2017), Lower Mustang, Upper Manang and Sagarmatha National Park (Shrestha et al. 2018)

(continued)

Table 2.2 (continued)

Domestic	Common names	Regions and references
Myodes regulus	Royal vole	Manang, central Nepal (Oli 1993)
Ovibos sp.	Ox	Manang, central Nepal (Oli 1993), Samagaun, Manaslu Conservation Area (Bhattarai 2015), Lower Mustang, Upper Manang and Sagarmatha National Park (Shrestha et al. 2018)
Ovis sp.	Sheep	Manang, central Nepal (Oli 1993), Phu valley, Manang (Wegge et al. 2012), Nepal (Lovari et al. 2013a), Manang and Mustang (Aryal et al. 2014a), Manaslu Conservation Area, Gorkha (Chetri et al. 2017)
Taurus/indicus/Yak hybrid	Lulu cow	Manaslu Conservation Area, Gorkha (Chetri et al. 2017)

Birds	Common names	Regions and references
Lophophorus impejanus	Impheyan pheasant	Chhekampar VDC, Gorkha, Manaslu Conservation Area (Devkota et al. 2017)
Tetraogallus tibetanus	Tibetan snow cock	upper Langtang National Park (Chalise 2011), Shey Phoksundo National Park (Devkota et al. 2013)
	Game birds	Langu valley, west Nepal (Jackson and Ahlborn 1988)
	Birds – Galliformes	Everest region (Lovari et al. 2009)
	Phasianidae	Nepal (Lovari et al. 2013a)
	Birds	Manang, central Nepal (Oli 1993), Dhorpatan Hunting Reserve (Aryal 2009), Upper Mustang (Aryal 2011), Phu valley, Manang (Wegge et al. 2012), Manang and Mustang (Aryal et al. 2014a), Manaslu Conservation Area, Gorkha (Chetri et al. 2017), Lower Mustang, Upper Manang and Sagarmatha National Park (Shrestha et al. 2018)

Plant	Common names	Regions and references
Myricaria rosea	–	Everest region (Lovari et al. 2013b)
Myricaria sp.	Tamaricaceae spp.	Everest region (Lovari et al. 2013b)
	Grasses	Lower Mustang, Upper Manang and Sagarmatha National Park (Shrestha et al. 2018)
	Vegetation	Dhorpatan Hunting Reserve (Aryal 2009), Lower Mustang, Upper Manang and Sagarmatha National Park (Shrestha et al. 2018)

Unknown	Common names	Regions and references
	Non-food items	Dhorpatan Hunting Reserve (Aryal 2009)

only in summer, whereas in the Annapurna Conservation Area, the main prey is blue sheep in winter and yak and goat in summer. Snow leopard prefers large prey and avoids small prey in summer, but not in winter. In Sagarmatha National Park, wild prey is eaten only in winter (Shrestha et al. 2018).

For snow leopards, medium-large prey weighs 51–75 kg and small prey 2–25 kg (Lovari et al. 2009). The relation between snow leopard and its main prey, blue sheep, in terms of weight was 1:113–181 in 1989–1990 (Oli 1991) and 1:114–159 in 1990–1991 (Oli 1994). In the upper Mustang region, there are 0.86 blue sheep per km^2 and a total biomass of approximately 38,925 kg. This could support nearly 19 snow leopards (1.6 snow leopards/100 km^2) (Aryal et al. 2014b). The density of blue sheep is much higher at Chhekampar VDC, Gorkha and Manaslu Conservation Areas (3.8 animals/km^2) and thus these areas could support more snow leopards (Devkota et al. 2017).

Livestock also makes up an important part of the diet of snow leopards. Domestic animals such as goat, yak and cows are reported as food for snow leopard (Shrestha et al. 2019). Figures have shown that 42% of snow leopard's diet consists of domestic animals in the Phu valley, Manang (Wegge et al. 2012) and 54.54% in the Sagarmatha (Everest) region (Shrestha 2008). Chetri et al. (2017) report that livestock are killed more frequently by male snow leopards (males: 47%, females: 21%) and wild ungulates more frequently by female snow leopards (males: 48%, females: 70%).

2.5 Human-Snow Leopard Conflict and Public Attitude to Conservation in Nepal

Killing of livestock by snow leopards is quite common in Nepal (Ikeda 2004; Shrestha et al. 2012; Wegge et al. 2012; Aryal 2013; Devkota et al. 2017). Generally, during alpine winter (December–April) livestock on pastures is the most vulnerable, especially young calves (1–3 years of age) (Ikeda 2004). They are also more at risk in areas, where there are bushes, forest, boulders, crevices and depressions (Khatiwada and Ghimirey 2009; Sherchan and Bhandari 2017). The losses vary from place to place. In the Lelep VDC, it increased from 17.2% in 2005 to 28% in 2014, whereas at Yampdhudin it decreased from 8.9% in 2005/06 to 6% in 2014/15. Both of these villages are located inside the Kanchenjunga Conservation Area (Sherchan and Bhandari 2017). Annual percentage losses due to depredation by snow leopards ranged from 1.29 to 63%, and the number of domestic animals killed ranged from 12 to 412. Although in the Annapurna Conservation Area (ACA) and the Manaslu Conservation Area (MCA) the predation percentage was low (0.9%), the snow leopard was responsible for more than a half of it (61.9%) (Chetri et al. 2019a; Table 2.3).

The killing of livestock by snow leopards is costly for the herders in Nepal, and most of them favour extermination of snow leopards as the best way to resolve this problem (Poudel et al. 2008; Khatiwada and Ghimirey 2009; Ale 2010). In Rowaling, people have a mixed response towards snow leopards, with over half of

Table 2.3 Animals killed by snow leopard in Nepal (1991–2017). Dash (–) Data not available

Regions	Total loss percentage	Animals killed by snow leopard	Reported by
Manang, Annapurna conservation area, central Nepal	2.6	72	Oli (1991)
Khangshar, Annapurna conservation area, central Nepal	63	200	Jackson (1996)
Chhekampar VDC, Gorkha, Manaslu conservation area	1.29	12	Devkota et al. (2017)
Langtang, central Nepal	31.8	273	Adhikari (2004)
Phu valley, Annapurna conservation area, central Nepal	3.87	–	Conradi (2006)
Sagarmatha National Park	54.4	18	Shrestha (2008)
Humla, West Nepal	–	16	Khatiwada and Ghimirey (2009)
Dolphu, Phoksundo, Vijer and Saldang, Shey Phoksundo National Park	47.33	257	Bhudhathapa (2011)
Phu valley, Annapurna Conservation Area, central Nepal	15.1	159	(Wegge et al. 2012)
Shey Phoksundo National Park, west Nepal	45.6	412	(Devkota et al. 2013)
Manang-Mustang, Annapurna Conservation Area, central Nepal	18.4	–	(Aryal et al. 2014a)
Lower Mustang (LM), Upper Manang (UM) and Sagarmatha National Park (SNP)	–	250 (LM-92, UM-93, SNP-65)	(Shrestha et al. 2018)
Annapurna Conservation Area (ACA) and the Manaslu conservation area (MCA)	61.9	–	(Chetri et al. 2019a)

the livestock owners (57%) with no specific desire to minimize livestock killing by snow leopards and 23% in favour of eradicating snow leopards. Only 10% of the herders favoured mitigation measures, while the rest (10%) believed it could be reduced by performing religious ceremonies (Ale 2010). In the Kanchenjunga Conservation Area, local herders think that if the killing of snow leopards is to be

banned, then they should be compensated for their loses and management in terms of reliability, and transparency should be tested before the initiation of such a livestock insurance policy (Ikeda 2004).

Study in the Sagarmatha National Park carried out by Hanson et al. (2018) have examined how local communities that responded to the idea of translocation of the prey species—blue sheep into the Sagarmatha National Park in Nepal to reduce the predation of livestock by snow leopard. The result showed that herders were reluctant because they feared crops would be damaged and competition for pasture more than the loss of livestock.

In the Sagarmatha National Park and the Annapurna Conservation Area, Hanson et al. (2019b) found a high percentage of local people had positive (60.5%) attitudes towards snow leopard, 19.0% were neutral, 16.5% were negative and 4.1% were very negative. Positive attitudes because of cultural and religious values were the most common and negative reasons because of the challenges of coexisting with a predatory species and its real or perceived danger to livestock. Kusi et al. (2019) conducted a survey of people's perception of snow leopard conservation in upper Humla, upper Dolpa, and Kanchenjunga Conservation Area in Nepal. They found that overall attitudes were more positive towards snow leopard than the Himalayan wolf *Canis* sp., which commonly attacks livestock.

In the past, herders often killed snow leopards at Manang (Oli et al. 1993, 1994) and in the Langu valley (Jackson 1979a). However, after the establishment of the Annapurna Conservation Area, the residents at Mustang and Manang became more reluctant to hunt snow leopards for fear of being reported or fined by the government and instead of killing them they chased them away (Jackson et al. 1996). In other places in Nepal, such as in the Langtang National Park (Adhikari 2004) and at Humla (Khatiwada and Ghimirey 2009), retaliatory killing and poaching of snow leopards continues.

Despite the existence of people-snow leopard conflicts, there are also reports of a positive attitude towards snow leopards in the Manaslu Conservation Area, Gorkha (Ale et al. 2014; Devkota et al. 2017). This is because most of the people in this area are Buddhist. They believe that snow leopards are ambassadors of god and that the presence of snow leopards in their area is a matter of dignity. Traditionally, killing and hunting is strictly forbidden in the restricted zone. If anyone uses violence against snow leopards, this goes against their social norms, and must be punished by Lamas (local priests).

Recently, Schutgens et al. (2018) surveyed willingness to pay for conservation of snow leopard in the Annapurna Conservation Area, Nepal. Out of 406 foreign tourists, it was found that 49% of visitors stated that they would pay additional fees for conservation of snow leopard. However, the majority of visitors were unwilling to pay additional fees, as they thought that the fee paid to the Conservation Area was already expensive. Similarly, tourists also expressed their views in supporting snow leopard conservation in Annapurna Conservation Area, Nepal. This shows that wildlife tourism could be employed as an important tool to conserve snow leopard (Hanson et al. 2019a).

2.6 Threat and Trade in Nepal

The threats in the Dolphu region and Shey Phoksundo National Park are due to weak enforcement of the law, unregulated livestock grazing and human pressure. Moreover, there is a great human pressure on snow leopard habitat, especially during the collection of *Ophiocordyceps sinensis* (formerly known as *Cordyceps sinensis*) *or yartsa gunbu* (Poudel et al. 2008). Decrease in natural prey and increase in the use of alpine pastures by humans and their livestock in the Langu valley also threatens the survival of snow leopards (Jackson 1979a). Livestock and wild ungulates spatial overlap and grazing competition are responsible for habitat degradation (Shrestha 2006; Shrestha et al. 2012). Depletion of its prey population (such as blue sheep, Himalayan tahr, Himalayan musk deer) is the main reason for the decrease in the abundance of snow leopards (Kyes and Chalise 2005; Chalise 2011; Ferretti et al. 2014). Deforestation, habitat fragmentation, unmanaged use of pastures and tourists (Adhikari 2004; Upadhyay 2010), along with hunting and killing snow leopards for their pelts and bones, which can be sold for high prices (Jackson 1979b; Jackson and Ale 2009), are the main threats to snow leopard survival. In addition to this, Khanal et al. (2018) found that human disturbance and habitat degradation associated with extraction of non-timber forest products, livestock grazing and poaching are major threats to snow leopards in the Api Nampa Conservation Area (Khanal et al. 2018).

There is no formal record of snow leopards' skin and bones trade in Nepal that was mainly carried out by Kashmiri traders in Kathmandu until 1980. Despite the increase in the publicity directed at conserving snow leopards, this trade continues, but surreptitiously. Currently, there is a trade of body parts of snow leopards and tiger bones with Tibet, but no evidence of a trade of live animals (Dexel and Deutschland 2002). Recently, during a monitoring of data for snow leopard from 2003 to 2014, Maheshwari and Niraj (2018) showed that in Nepal there were five cases of trade of snow leopard parts. Of the 5 cases, 3 were recorded in the literature and 2 were based on questionnaire surveys.

2.7 Conservation Measures in Nepal

In Nepal, snow leopards are legally protected under the National Parks and Wildlife Conservation Act 2029 (HMGN 1973). The fourth amendment of this Act 2049 (HMGN 1993) defined the penalties for poaching snow leopards, or acquiring, buying and selling their pelts (Kharel et al. 2001). The penalty is either a fine of Rs. 50,000–100,000 or a prison sentence of 5–15 years, or both. There are also meetings between governmental and non-governmental agencies with an interest in or jurisdictional responsibilities for wild life legalization in this country, which have also boosted interest in conservation (Heinen et al. 1995). The holistic integrated programs launched by the Department of National Parks and Wildlife Conservation (DNPWC), The National Trust for Nature Conservation (NTNC) (previously

the King Mahendra National Trust for Nature Conservation, KMTNC), World Wide Fund For Nature in Nepal (WWF Nepal), International Centre for Integrated Mountain Development (ICIMOD), Snow Leopard Conservation Committees (SLCC), etc. have also contributed to the conservation of snow leopards in Nepal (Ale and Karky 2002). It is also proposed that prey, such as blue sheep, should be translocated (Aryal et al. 2013), and corridors between different national parks (for example, Makalu Barun and Sagarmatha) maintained (Ale 2010) in order to protect snow leopards. The Government of Nepal has outlined snow leopard conservation plans (2005–2015 and 2011–2021) aimed at consolidating ongoing initiatives and addressing contemporary issues and challenges of snow leopard and their habitats conservation (GoN/DNPWC and WWF Nepal 2013; GoN/DNPWC 2017).

The first community-based Livestock Insurance Scheme (LIS) was initiated in KCA with the support of WWF Nepal in order to mitigate human-snow leopard conflict in 2006 (GoN/DNPWC 2017). This policy aims to compensate affected households for the loss of their livestock caused by snow leopards (Anonymous 2017) and is regulated by the Snow Leopard Conservation Committees (SLCC) in the area. The intention is to enable people to cope with the situation and so reduce the retaliatory killings of snow leopards (Anonymous 2017; WWF Nepal 2007). The government of Nepal has also formulated the 13th plan (2013/14–2015/16) covering the agriculture/livestock development policies, which formalizes the provision of insurance for loses of livestock and agriculture produce (Pradhanang et al. 2015). It is thus necessary to expand LIS to all the places where human-snow leopard conflicts occur.

2.8 Future Perspectives

In Nepal, snow leopards are well established in the northern part of the country in an area of 30,000 km^2 at altitudes between 2900 and 6000 m. Despite the remoteness and inaccessibility of the habitats of snow leopards they are relatively well studied in Nepal. The first studies were of their home ranges and movements. The objectives of the studies gradually changed with the advent of camera traps and genetic analysis. However, there is a constant need for development of new and improved methods, as those available today are often not able to determine the gender of snow leopards (Conradi 2006). A considerable number of studies highlight that the killing of livestock by snow leopards results in herders often having a negative attitude towards snow leopards, which leads to retaliatory killing and contributes to the decline in their abundance. The livestock insurance policy, which was initiated in the Kanchenjunga Conservation Area in eastern Nepal, is a milestone in the increase of awareness and development of positive attitudes towards snow leopards, which will ultimately protect them. As most effective conservation measures involve community-based participation, it would be a great achievement if local people could be trained to

record marks and store scat or hairs in local repositories prior to making them available to ecologists. This new, but not yet practiced approach could be an important part of public awareness programs.

Studies on snow leopard diet reveal that it feeds on relatively few animals and depends on the availability of small mammals, birds or even livestock. Thus, it is important to protect those areas where the natural prey of snow leopards occurs. Local community-based programs that result in people not killing animals, as at Gorkha (Devkota et al. 2017), is one method of improving the conservation of snow leopards. Other community-based programs, which could help in their conservation, are field patrols, provision of livestock insurance, construction of predator-proof night time corrals and other means of protecting livestock, managed livestock grazing and establishment of a conservation-based tourism program to bring additional income to local communities.

Recording of reproduction, diseases and real time movements of snow leopard using satellite based global positioning system (GPS) are yet to be explored in Nepal. Illegal killing and poaching for trade are important issues yet to be addressed. Competition with other animals for food and habitat (Lovari et al. 2013a), or a simple comparison of the past and present abundance of snow leopards or their prey are also lacking in Nepal (Ghoshal et al. 2017). As emphasized above it is also important to take into account in-situ conservation and minimize conflict while promoting a positive attitude towards snow leopard (Lama et al. 2020).

References

Adhikari JN (2004) Ecological study of the snow leopard *Uncia uncia* (Schreber 1775) in Langtang national park. Nepal. M.Sc. thesis, Tribhuvan University

Ahlborn GG, Jackson RM (1988) Marking in free-ranging snow leopard in west Nepal: a preliminary assessment. In: Freeman H (ed) International snow leopard symposium 5. pp 24–49

Ale SB (2005) Have snow leopards made a comeback to the Everest region of Nepal? University of Illinois at Chicago, Chicago

Ale SB (2007) Ecology of the snow leopard and Himalayan tahr in Sagarmatha (Mt. Everest) national park, Nepal. Ph.D. thesis, University of Illinois at Chicago

Ale SB (2010) Assessment of snow leopards and their corridors in Nepal's east Himalayan ecoregion. Rufford Small Grants, UK.

Ale SB, Boesi R (2005) Snow leopard sightings on the top of the world. Cat News 43:19–20

Ale SB, Karky BS (2002) Observations on conservation of snow leopards in Nepal. In: Contributed papers to the snow leopard survival strategy summit. The International Snow Leopard Trust, pp 3–14

Ale SB, Shrestha B, Jackson R (2014) On the status of snow leopard *Panthera uncia* (Schreber 1775) in Annapurna. Nepal. J Threat Taxa 6:5534–5543

Anonymous (2017) Snow leopard. In: Snow Leopard. Available from URL: http://www.wwfnepal.org/what_we_do/wildlife/snow_leopard/. Accessed 18 Dec 2017

Aryal A (2009) Final report on demography and causes of mortality of Blue sheep (*Pseudois nayaur*) in Dhorpatan hunting reserve in Nepal. Snow Leopard Conservation Grant Program

Aryal A (2011) Conservation of Snow leopard *Uncia uncia* in Mustang district of Annapurna Conservation Area (ACA) of Nepal. Pro Natura Fund

Aryal A (2013) Prey, predator, human and climate interactions in the Himalaya, Nepal. Ph.D. thesis, Massey University, Auckland, New Zealand

Aryal A, Brunton D, Ji W, Karmacharya D, McCarthy T, Bencini R, Raubenheimer D (2014a) Multipronged strategy including genetic analysis for assessing conservation options for the snow leopard in the central Himalaya. J Mammal 95:871–881. https://doi.org/10.1644/13-MAMM-A-243

Aryal A, Brunton D, Ji W, Raubenheimer D (2014b) Blue sheep in the Annapurna Conservation Area, Nepal: habitat use, population biomass and their contribution to the carrying capacity of snow leopards. Integr Zool 9:34–45. https://doi.org/10.1111/1749-4877.12004

Aryal A, Brunton D, Raubenheimer D (2013) Habitat assessment for the translocation of blue sheep to maintain a viable snow leopard population in the Mt Everest Region. Nepal. Zool Ecol 23:66–82

Aryal A, Shrestha UB, Ji W, Ale SB, Shrestha S, Ingty T, Maraseni T, Cockfield G, Raubenheimer D (2016) Predicting the distributions of predator (snow leopard) and prey (blue sheep) under climate change in the Himalaya. Ecol Evol 6:4065–4075. https://doi.org/10.1002/ece3.2196

Bhattarai B (2015) Diet analysis of snow leopard in Manaslu Conservation Area: a case from Samagaun VDC, Gorkha. Central Department of Environmental Science, Tribhuvan University, Kirtipur, Nepal

Bhudhathapa B (2011) Distribution of modelling of snow leopard (*Uncia uncia*) in midwestern trans Himalayas of Nepal. Rufford Small Grants, UK

Cardillo M, Mace GM, Jones KE, Bielby J, Bininda-Emonds OR, Sechrest W, Orme CD, Purvis A (2005) Multiple causes of high extinction risk in large mammal species. Science 309:1239–1241. https://doi.org/10.1126/science.1116030

Chalise MK (2011) Snow Leopard (*Uncia uncia*), prey species and outreach in Langtang national, park. Nepal. Our Nat 9:138–145

Chetri M (2018) Ecology of snow Leopards in the Central Himalayas, Nepal. Ph.D. thesis, Faculty of Applied Ecology, Agricultural Sciences and Biotechnology, Inland Norway University of Applied Sciences, Norway

Chetri M, Odden M, Devineau O, Wegge P (2019a) Patterns of livestock depredation by snow leopards and other large carnivores in the Central Himalayas, Nepal. Glob Ecol Conserv e00536. https://doi.org/10.1016/j.gecco.2019a.e00536

Chetri M, Odden M, Sharma K, Flagstad O, Wegge P (2019b) Estimating snow leopard density using fecal DNA in a large landscape in north-central Nepal. Glob Ecol Conserv e00548. https://doi.org/10.1016/j.gecco.2019b.e00548

Chetri M, Odden M, Wegge P (2017) Snow leopard and Himalayan wolf: food habits and prey selection in the central Himalayas. Nepal. Plos ONE 12:e0170549

Conradi M (2006) Non-invasive sampling of snow leopards (*Uncia uncia*) in Phu valley, Nepal. Master of Science, Department of Biology, University of Oslo

Devkota BP, Silwal T, Kolejka J (2013) Prey density and diet of snow leopard (*Uncia uncia*) in Shey Phoksundo national park. Nepal. Appl Ecol Env Sci 1:55–60. https://doi.org/10.12691/aees-1-4-4

Devkota BP, Silwal T, Shrestha BP, Sapkota AP, Lakhey SP, Yadav VK (2017) Abundance of snow leopard (*Panthera uncia*) and its wild prey in Chhekampar VDC, Manaslu Conservation Area. Nepal. Banko Janakari 27:11–20

Dexel B, Deutschland N (2002) The illegal trade in snow leopards: a global perspective. German Society for Nature Conservation Berlin, Germany

Ferretti F, Lovari S, Minder I, Pellizzi B (2014) Recovery of the snow leopard in Sagarmatha (Mt. Everest) national park: effects on main prey. Eur J Wildl Res 60:559–562. https://doi.org/10.1007/s10344-014-0810-7

Forrest JL, Wikramanayake E, Shrestha R, Areendran G, Gyeltshen K, Maheshwari A, Mazumdar S, Naidoo R, Thapa GJ, Thapa K (2012) Conservation and climate change: assessing the vulnerability of snow leopard habitat to treeline shift in the Himalaya. Biol Conserv 150:129–135. https://doi.org/10.1016/j.biocon.2012.03.001

Fox JL (1989) A review of the status and ecology of the snow leopard (*Panthera uncia*). International Snow Leopard Trust

Ghoshal A, Bhatnagar YV, Pandav B, Sharma K, Mishra C, Raghunath R, Suryawanshi KR (2017) Assessing changes in distribution of the Endangered snow leopard *Panthera uncia* and its wild prey over 2 decades in the Indian Himalaya through interview-based occupancy surveys Oryx 1–13. https://doi.org/10.1017/S0030605317001107

GoN/DNPWC (2017) Snow leopard conservation action plan (2017–2021). Department of National Parks and Wildlife Conservation, Ministry of Forests and Soil Conservation, Government of Nepal, PO Box 860, Babarmahal, Kathmandu, Nepal

GoN/DNPWC and WWF Nepal (2013) Snow leopard action plan for Nepal 2005–2015 (Revised 2012). Department of National Parks and Wildlife Conservation, Ministry of Forests and Soil Conservation, Government of Nepal, PO Box 860, Babarmahal, Kathmandu Nepal

Hanson JH (2017) Snow leopards and sustainability: livelihoods, governance and coexistence in the Nepal Himalayas. Ph.D. thesis, University of Cambridge

Hanson JH, Schutgens M, Lama RP, Aryal A, Dhakal M (2018) Local attitudes to the proposed translocation of blue sheep *Pseudois nayaur* to Sagarmatha National Park. Nepal. Oryx 54:344–350. https://doi.org/10.1017/S0030605318000157

Hanson JH, Schutgens M, Baral N (2019a) What explains tourists' support for snow leopard conservation in the Annapurna Conservation Area, Nepal? Hum Dimens Wildl 24:31–45. https://doi.org/10.1080/10871209.2019.1534293

Hanson JH, Schutgens M, Leader-Williams N (2019b) What factors best explain attitudes to snow leopards in the Nepal Himalayas? PLoS ONE 14:e0223565. https://doi.org/10.1371/journal.pone.0223565

Heinen JT, Yonzon PB, Leisure B (1995) Fighting the illegal fur trade in Kathmandu. Nepal. Conserv Biol 9:246–248

Hillard D (1990) Vanishing tracks: four years among the snow leopards of Nepal. Arbor House Pub Co., New York

HMGN (1973) National parks and wildlife conservation act 2029. Nepal Gazette 2029-11-28 B.S. Ministry of Law, Justice and Parliamentary Affairs, HMGN, Kathmandu, Nepal

HMGN (1993) Forest act 2049. Ministry of Law, Justice and Parliamentary Affairs, HMGN, Kathmandu, Nepal

Hoffmann M, Hilton-Taylor C, Angulo A et al (2010) The impact of conservation on the status of the world's vertebrates. Science 330:1503–1509. https://doi.org/10.1126/science.1194442

Ikeda N (2004) Economic impacts of livestock depredation by snow leopard *Uncia uncia* in the Kanchenjunga Conservation Area, Nepal Himalaya. Environ Conserv 31:322–330. https://doi.org/10.1017/S0376892904001778

Jackson R (1979a) Snow leopards in Nepal. Oryx 15:191–195

Jackson R (1979b) Aboriginal hunting in west Nepal with reference to musk deer *Moschus moschiferus moschiferus* and snow leopard *Panthera uncia*. Biol Conserv 16:63–72. https://doi.org/10.1016/0006-3207(79)90008-9

Jackson R, Ahlborn GG (1984) Preliminary habitat suitability model for the snow leopard *Panthera uncia* in west Nepal. Int Pedigree Book Snow Leopards 4:43–52

Jackson R, Ahlborn GG (1988) Observations on the ecology of snow leopard in west Nepal. In: Freeman H (ed) Proceedings of the 5th international snow leopard symposium, pp 65–87

Jackson R, Ahlborn G (1989) Snow leopard (*Pathera uncia*) in Nepal—home range and movements. Natl Geogr Res 5:161–175

Jackson R, Hunter DO (1996) Snow leopard survey and conservation handbook. International Snow Leopard Trust, Seattle, Washington and U.S. Geological Survey, Fort Collins Science Center, Colorado

Jackson RM (1996) Home range, movements and habitat use of snow leopard (*Uncia uncia*) in Nepal. Ph.D. thesis, University of London, United Kingdom

Jackson RM, Ahlborn GG, Gurung M, Ale S (1996) Reducing livestock depredation losses in the Nepalese Himalaya. In: Timm RM, Crabb AC (eds) Proceedings of the seventeenth vertebrate pest

conference March 5–7, University of California, Davis November 1996, Rohnert Park, California, USA, pp 241–247
Jackson RM, Ale SB (2009) Snow leopard: Is reintroduction the best option? In: Hayward M, Somers MJ (eds) Reintroduction of top-order predators. Wiley-Blackwell, Chichester, pp 164–185
Janecka JE, Zhang Y, Li D et al (2017) Range-wide snow leopard phylogeography supports three subspecies. J Hered 108:597–607. https://doi.org/10.1093/jhered/esx044
Karmacharya D, Manandhar S, Shakya J et al (2016) Incidental discovery of non-focal carnivore species during genetic study of Bengal tiger (*Panthera tigris tigris*) and snow leopard (*Panthera uncia*) in Nepal. Asian J Conserv Biol 5:81–88
Karmacharya DB, Thapa K, Shrestha R, Dhakal M, Janecka JE (2011) Noninvasive genetic population survey of snow leopards (*Panthera uncia*) in Kangchenjunga Conservation Area, Shey Phoksundo National Park and surrounding buffer zones of Nepal. BMC Res Notes 4:516
Khanal G, Poudyal LP, Devkota BP, Ranabhat R, Wegge P (2018) Status and conservation of the snow leopard *Panthera uncia* in Api Nampa Conservation Area. Nepal. Oryx 54:421–428. https://doi.org/10.1017/S0030605318000145
Kharel FR, Khatri TB, Rayamajhi S (2001) Forest, wildlife and watershed management through landscape planning approach in Nepal. Banko Janakari 11:36–38
Khatiwada JR, Chalise MK (2006) Status of snow leopard and conflict perception in Kangchenjunga Conservation Area, eastern Nepal. Nepalese J Zool 1:1–8
Khatiwada JR, Ghimirey Y (2009) Status of snow leopard (*Uncia uncia*) in Humla district, western Nepal. Sci World 7:49–52
Kusi N, Sillero-Zubiri C, Macdonald DW, Johnson PJ, Werhahn G (2019) Perspectives of traditional Himalayan communities on fostering coexistence with Himalayan wolf and snow leopard. Conserv Sci Prac 2:1–16. https://doi.org/10.1111/csp2.165
Kyes RC, Chalise MK (2005) Assessing the status of the snow leopard population in Langtang National Park, Nepal. International Snow Leopard Trust
Laakso M, Welling P, Bukvova H, Nyman L, Björk B-C, Hedlund T (2011) The development of open access journal publishing from 1993 to 2009. PLoS ONE 6:e20961. https://doi.org/10.1371/journal.pone.0020961
Lama RP, Ghale TR, Regmi GR (2020) Snow Leopards in 2100: towards a real-world nepal perspective. In: Regmi GR, Huettmann F (eds) Hindu Kush-Himalaya watersheds downhill: landscape ecology and conservation perspectives, first. Springer International Publishing, Cham, pp 677–684
Lama RP, Ghale TR, Suwal MK, Ranabhat R, Regmi GR (2018) First photographic evidence of Snow Leopard *Panthera uncia* (Mammalia: Carnivora: Felidae) outside current protected areas network in Nepal Himalaya. J Threat Taxa 10:12086. https://doi.org/10.11609/jott.3031.10.8.12086-12090
Lovari S, Boesi R, Minder I, Mucci N, Randi E, Dematteis A, Ale SB (2009) Restoring a keystone predator may endanger a prey species in a human-altered ecosystem: the return of the snow leopard to Sagarmatha National Park: restoring a keystone predator may endanger a prey species in a human-altered ecosystem. Anim Conserv 12:559–570. https://doi.org/10.1111/j.1469-1795.2009.00285.x
Lovari S, Minder I, Ferretti F, Mucci N, Randi E, Pellizzi B (2013a) Common and snow leopards share prey, but not habitats: competition avoidance by large predators? J Zool 291:127–135. https://doi.org/10.1111/jzo.12053
Lovari S, Ventimiglia M, Minder I (2013b) Food habits of two leopard species, competition, climate change and upper treeline: a way to the decrease of an endangered species? Ethol Ecol Evol 25:305–318. https://doi.org/10.1080/03949370.2013.806362
Lyngdoh S, Shrotriya S, Goyal SP, Clements H, Hayward MW, Habib B (2014) Prey preferences of the snow leopard (*Panthera uncia*): regional diet specificity holds global significance for conservation. PLoS ONE 9:e88349. https://doi.org/10.1371/journal.pone.0088349
Maheshwari A, Niraj SK (2018) Monitoring illegal trade in snow leopards: 2003–2014. Global Ecol Conserv 14:e00387. https://doi.org/10.1016/j.gecco.2018.e00387

Matthiessen P (1978) The snow leopard. The Viking press, New York
McCarthy T, Mallon D, Nyhus PJ (eds) (2016) Snow leopards. Academic Press is an imprint of Elsevier, London, San Diego
McCarthy TM, Chapron G (2003) Snow leopard survival strategy. International Snow Leopard Trust and Snow Leopard Network. Seattle, USA
Oli MK (1991) The ecology and conservation of the snow leopard (*Panthera uncia*) in the Annapurna Conservation Area, Nepal. Master of Philosophy, University of Edinburgh
Oli MK (1993) A key for the identification of the hair of mammals of a snow leopard (*Panthera uncia*) habitat in Nepal. J Zool 231:71–93. https://doi.org/10.1111/j.1469-7998.1993.tb05354.x
Oli MK (1994) Snow leopards and blue sheep in Nepal: densities and predator: prey Ratio. J Mammal 75:998–1004. https://doi.org/10.2307/1382482
Oli MK (1997) Winter home range of snow leopards in Nepal. Mammalia 61:355–360
Oli MK, Taylor IR, Rogers DM (1993) Diet of the snow leopard (*Panthera uncia*) in the Annapurna Conservation Area. Nepal. J Zool 231:365–370
Oli MK, Taylor IR, Rogers ME (1994) Snow leopard *Panthera uncia* predation of livestock: an assessment of local perceptions in the Annapurna Conservation Area,. Nepal. Biol Conserv 68:63–68. https://doi.org/10.1016/0006-3207(94)90547-9
Poudel BS, Pant G, Bhagat SK, Gurung GB, Lama N (2008) Snow leopard monitoring in Dolphu of Shey Phoksundo national park, Nepal. National Parks and Wildlife Conservation, Kathmandu and Shey Phoksundo National Park, Dolpa
Pradhanang U, Pradhanang S, Sthapit A, Krakauer NY, Jha AK, Lakhankar T (2015) National livestock policy of Nepal: needs and opportunities. Agriculture 5:103–131. https://doi.org/10.3390/agriculture5010103
Ripple WJ, Chapron G, López-Bao JV et al (2016) Saving the world's terrestrial megafauna. Bioscience 66:807–812. https://doi.org/10.1093/biosci/biw092
Schaller GB (1973) On the behaviour of blue sheep (*Pseudois nayaur*). J Bombay Nat Hist Soc 93:523–537
Schaller GB (1977) Mountain monarchs: mountain sheep and goats of the Himalaya. University of Chicago, Chicago
Schutgens MG, Hanson JH, Baral N, Ale SB (2018) Visitors' willingness to pay for snow leopard *Panthera uncia* conservation in the Annapurna Conservation Area, Nepal. Oryx 1–10. https://doi.org/10.1017/S0030605317001636
Sherchan R, Bhandari A (2017) Status and trends of human-wildlife conflict: a case study of Lelep and Yamphudin region, Kanchenjunga Conservation Area, Taplejung,. Nepal Conserv Sci 5:19–25
Shrestha A, Thapa K, Subba SA, Dhakal M, Devkota BP, Thapa GJ, Shrestha S, Malla S, Thapa K (2019) Cats, canines, and coexistence: dietary differentiation between the sympatric Snow Leopard and Grey Wolf in the western landscape of Nepal Himalaya. J Threat Taxa 11:13815–13821. https://doi.org/10.11609/jott.4217.11.7.13815-13821
Shrestha B (2004) Status, distribution, predator impact, crop depredation and mitigation measures of Himalayan tahr in Sagarmatha National Park. A report submitted to Department of National Parks and Wildlife Conservation, Nepal and Tourism for Rural Poverty Alleviation Programme (TRPAP)/UNDP, Nepal
Shrestha B (2006) Status, distribution and potential habitat of Himalayan tahr (*Hemitragus jemlahicus*), and conflict areas with livestock in Sagarmatha National Park. Nepal. Nepal J Sci Technol 7:27–33
Shrestha B (2008) Prey abundance and prey selection by snow leopard (*Uncia uncia*) in the Sagarmatha (Mt. Everest) national park, Nepal. International Snow Leopard Trust, Snow Leopard Conservancy, Snow Leopard Network
Shrestha B (2016) Interaction between sympatric species (snow leopard and co-predators) and their conservation in Annapurna Conservation Area, Nepal. The Rufford Small Grants for Nature Conservation, UK

Shrestha B, Aihartza J, Kindlmann P (2018) Diet and prey selection by snow leopards in the Nepalese Himalayas. PLoS ONE 13:e0206310. https://doi.org/10.1371/journal.pone.0206310

Shrestha B, Kindlmann P, Jnawali SR (2012) Interactions between the Himalayan tahr, livestock and snow leopards in the Sagarmatha National Park. In: Kindlmann P (ed) Himalayan diodiversity in the changing world. Springer, Dordrecht, pp 115–145

Thapa BB (2011) Snow Leopard conservation in Nepal: an overview. Department of National Parks and Wildlife Conservation, Ministry of Forests and Soil Conservation, Kathmandu, Nepal

Upadhaya S (2017) A final report on human-snow leopard (*Panthera uncia*) conflict in northern Nepal-Dolpa. Snow Leopard Conservation Grant Program, Snow Leopard Network

Upadhyay M (2010) Relative abundance, habitat preference and threats of snow leopard *Uncia uncia* in upper Mustang, Nepal. M.Sc. thesis, Institute of Forestry, Tribhuvan University, Pokhara, Nepal

Valentová KA (2017) Abundance and threats to the survival of the snow leopard—a review. Eur J Environ Sci 7:73–93. https://doi.org/10.14712/23361964.2017.7

Wegge P, Shrestha R, Flagstad Ø (2012) Snow leopard *Panthera uncia* predation on livestock and wild prey in a mountain valley in northern Nepal: implications for conservation management. Wildl Biol 18:131–141. https://doi.org/10.2981/11-049

Wolf M, Ale SB (2009) Signs at the top: habitat features influencing snow leopard *Uncia uncia* activity in Sagarmatha National Park. Nepal. J Mammal 90:604–611

WWF (2009) Estimating snow leopard population in the Nepal Himalaya. WWF Nepal Program, Baluwatar, Kathmandu

WWF Nepal (2007) Sustainable livelihood: livestock insurance. WWF Nepal, Baluwatar, Kathmandu